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DEPARTMENT OF FOOD AND RESOURCE ECONOMICS
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IFRO Report

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284

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This report can be read in the context of the report "Auction mechanisms for setting aside forest for biodiversity conservation". IFRO Commissioned Work 2018/02 written by Bo Jellesmark Thorsen, Jette Bredahl Jacobsen, Niels Strange, Mette Termansen & Thomas Hedemark Lundhede

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Dansk Sammendrag (Danish Summary)

Henlæggelse til urørt skov er en omkostningseffektiv måde at understøtte den langsigtede bevarelse af en betydelig andel af den truede biodiversitet i Danmark (Højgård et al, 2016). Urørt skov indebærer, at skovejeren stopper den forstlige aktivitet, dvs. stopper hugst, plantning, hegning osv. på arealet. Dette medfører et indtægtstab, som skovejeren skal kompenseres for, såfremt man fra samfundets side ønsker en sådan udlægning, men ikke ønsker at stille skovejeren ringere end før. Denne kompensation er hidtil blevet fastsat efter en tilskudsordning, hvor skovejere kompenseres efter en beregnet værdi af den stående vedmasse med et tillæg for tabt fremtidig produktion.

Det er blevet foreslået at omlægge kompensationsmekanismen til en form, hvor man anvender en såkaldt omvendt auktion, en slags licitationsmodel. Denne note beskriver nogle af de essentielle elementer, der skal implementeres for at foretage dette skifte. Centralt i den omvendte auktion er det, at skovejeren her afgiver et tilbud på at stoppe skovdriften på et givet areal for en given pris og samtidig beskriver arealet efter bestemte parametre, der er relevante for arealets potentiale for biodiversiteten. Det åbner det relevante spørgsmål om, hvordan man vælger mellem en serie relevante tilbud af varierende pris og kvalitet, således at man får mest kvalitet for pengene.

Vi foreslår her at benytte en såkaldt 'benchmarking'-procedure til at vælge mellem indkomne tilbud fra private skovejere. Benchmarking er i denne sammenhæng en sammenlignende tilgang, hvor en køber (her Miljøstyrelsen) identificerer den relative ydeevne af de indkomne bud, baseret på prisen og et antal andre parametre, som er relevante for arealets potentiale for biodiversiteten. Udvælgelsen kan foregå ved hjælp af Data Envelopment Analysis (DEA), som er en matematisk programmeringsmetode til at evaluere den relative efficiens af forskellige tilbud. Vi beskriver og illustrerer udvalgte tilgange til, hvordan man i praksis kan implementere en procedure for at udvælge de bedste tilbud vha. DEA. Vi diskuterer udfordringer ved de enkelte tilgange og illustrerer, hvordan de virker ved brug af et simuleret datasæt.

En ændring fra den nuværende kompensationsordning til en auktionsbaseret betalingsordning vil kræve, at den nuværende bekendtgørelse ændres, således at den kan omfatte teknikaliteterne i en omvendt auktion og den efterfølgende udvælgelse vha. DEA. Vi angiver derfor til sidst i denne note en række opmærksomhedspunkter, der skal håndteres, for at dette kan gøres.

1. Background

Setting aside forest land is a cost effective way to preserve biodiversity in Danish forests in the long-run (Højgård et al, 2016). In May 2016 the Danish Government launched a program to set aside forest land for biodiversity protection (Ministry of Environment and Food of Denmark, Naturpakken, 2016). The selected mechanism was to abolish forestry operations on selected state and privately owned land. In 2018 almost 14,000 hectares of state-owned forest land were selected under this program. The designated areas were identified with the aim to select high-biodiversity value areas in the most cost-effective way. The designation involves a 10 years transition period for deciduous forests and 50 years in case of coniferous forests. During these transition periods economic valuable timber resources can be extracted, but after the transition all harvesting is prohibited.

Private land owners will also be offered the possibility to set aside forest areas for biodiversity conservation purposes. Designations on private land will be based on voluntary commitments. Private land owners will receive compensation for their forgone income. Since 2017 a support grant scheme has been implemented to compensate private forest owners. It is expected, that up to 3,300 hectares of private land will be set aside.

A compensation for setting aside forest is essentially a purchase of harvesting rights from private forest owners. In 2018, Thorsen et al (2018) described how these rights can be offered to the government using a mechanism similar to a reversed auction. The present report builds on this work and thus should be read in conjunction with Thorsen et al (2018). Both reports address the implementation of auction mechanisms, with specific attention to designs and procedures that may enhance efficiency of public procurement for biodiversity protection. The reverse auction design may be more efficient than compensation through a support grant scheme as the requested price is driven by the forest owner's cost function of conserving forest land, especially the forgone income (Thorsen et al., 2018). Thus, the purpose of a reverse auction is to increase cost-effectiveness in procurement by accepting the lowest possible set of offers for the harvesting rights in biodiversity rich forest areas. A reversed auction is particularly interesting in a situation where the government is the only buyer of harvesting rights from many forest owners, in order to obtain efficiency. In addition to the price a number of different attributes of each forest area are important for the value of the environmental outcome, in terms of the biodiversity conservation potential in the short and the long run. Some will be known to the buyer and some will be unknown. We will subsequently refer to efficiency of the selection of offers as a selection where no additional output (i.e. biodiversity attribute) can be obtained without decreasing the output of another biodiversity attribute, within a given budget.

The policy relevant question in focus for this report is therefore how to select the set of areas, among those offered from owners, which seems likely to provide the best biodiversity conservation potential for the budget spend. This report suggests an efficient multi-attribute benchmarking procedure to select between the offered areas using data envelopment analysis (DEA), which ensures a focus on cost effectiveness in decisions. Specifically, we consider the case where a principal (i.e. the Environmental Protection Agency) will be looking for offers to accept among all given offers, taking into consideration their budget constraint. We describe and illustrate the foundations of the approach in an accessible way. We begin by outlining the ideal welfare economic approach to selecting alternatives, based on full information about preferences, as this provides a useful benchmark. We then present an approach that approximates preferences based on ranges of attribute weights, and illustrate how this approach can guide selection of alternatives. However, preferences and even relative weights approximations of preferences may not easily be specified in practice. Therefore, the final two examples are approaches to select the best set among offers in technically operational ways that rank all offers relative to each other with a focus on cost efficiency. We discuss challenges, merits and relevance in the current context of each of the methods. Finally, we briefly discuss an extension of DEA, the so-called Yard stick benchmarking algorithm, which may be considered in future for similar area selection cases.

Finally, to prepare the regulatory basis for using the proposed method, the current governmental executive order needs to be modified slightly. We therefore highlight aspects of the existing executive order that with advantage could be amended to allow for an efficient selection of offers.

The analysis in this report has been carried out as part of the project SINCERE (Spurring INnovations for forest eCosystem sERvices in Europe), which is a four-year project funded through the European Commission's Horizon 2020 program. The goal is to develop novel policies and new business models by connecting knowledge and expertise from practice, science and policy, across Europe and beyond and the application of reverse auctions and selection procedures contributes a part of this.

2. Benchmarking using Data Envelopment Analysis

Applying DEA for benchmarking and selection of offers from a reverse auction for harvesting rights rests on a set of requirements. More specifically, there is a regulator (the principal, in our case the Danish Environmental Protection Agency) who is inviting offers from a number of agents, that is the forest owners. The agents provide their offers, which are combinations of prices and information about the characteristics of the offer, such as area size and various nature quality indicators. These data may be supplemented with inventory data collected by the principal, e.g. visiting and recording additional data. These data are processed in a Data Envelopment Analysis (DEA) based benchmarking procedure that ensures a transparent selection based on efficiency.

One purpose of applying benchmarking is to enhance incentives for a certain behavior or to increase transparency when offering grants, payments or similar in public procurement. In a single input and multiple output setting, the regulator may assume that the cost function is increasing and convex, but have no *a priori* information about the shape of the cost function. For output based on area sizes this appears to be a fair assumption. By establishing the agents' or decision making units' (DMUs) cost functions from their offers, it is possible to better design and target the regulators' incentives. One aspect is the pre-contractual asymmetric information or adverse selection problem, making it possible for better-informed agents to extract information rent by claiming too high costs. Benchmarking focused on cost efficiency can limit this incentive problem, by introducing competition in efficiency among agents, as described in the earlier report by Thorsen et al. (2018).

Benchmarking is a comparative approach for the regulator to identify the relative performance of the offers. In the benchmarking terminology the DMUs make these offers here we may think of the forest owners' decision to offer a forest area with specific qualities, for a specific price, a cost, to the principal. The relative performance is estimated using DEA, which is a mathematical programming method for estimating production frontiers and evaluating the relative efficiency of different DMUs. The efficiency calculation is based on a number of input and output variables, where the input variables can be viewed as the variables that the principal wants to reduce (e.g. costs) and the output variables those, the principal wants to increase. In a situation with only one output and one input, and assuming a constant return to scale technology, the efficiency measure is simply a ratio of the output to the input, comparable to a benefit/cost ratio. It becomes somewhat less straightforward to calculate efficiency measures when several outputs and several inputs are involved. However, the necessary algorithms for doing this are part of standard open-source software. Using these algorithms, it is straightforward to calculate efficiency score of every DMU, describing how each DMU performs relative to the rest, and in particular to identify the best set of the DMUs. The software algorithm estimation identifies the efficiency frontier assuming a convex combination of the best DMU's and calculate efficiency scores for all DMUs relative to this frontier. We illustrate this procedure in simple intuitive graphs below.

One of the most important and difficult steps in model development is the choice of inputs, outputs and contextual variables (Bogetoft 2012). The setting can be compared to production theory, which defines the inputs as resources spend and outputs as the outcome of the process that has an external value. Here it is assumed that an increase in one input can lead to an increase of some output. Likewise, more of one output will require the use of more of at least one of the inputs. In the present case we operate with a single input (the offered cost) and multiple outputs (measures related to potential for biodiversity conservation) setting.

Unfortunately, the step of selecting inputs and output is poorly described in the literature and there is no solid guiding theory. This leaves us with rules of thumb or guidelines as presented in Dyson et al. (2001) and Bogetoft (2012). These suggest that the variables selected to describe the production model should be relevant, complete, operational, independent, and non-redundant. This involves identifying and choosing inputs and outputs that, as far as possible, describe the production system we aim to model. Dyson et al. (2001) formulate it as the set of input and output data that fully cover the production process and the range of resources and products. Further, if possible, all units and environmental factors (reflecting non-homogenous environment) that affect the process should also be accounted for and used if not in the first stage analysis then potentially in a second stage analysis or evaluation procedure.

Relevance means that the set of variables should reflect the industry's comprehension of the system. *Completeness* means that the set of variables fully captures the inputs (resources) that go into the production, the structural characteristics that ease or complicate the production, and the quality aspects of outputs (products and services) that come out of the process. *Operational* makes it preferable to use variables that are unambiguously defined and measurable. Qualitative indexes and subjective assessments of utility or service values are less suitable in this sense. Ordinal variables are best considered using groupings or in a second-stage analysis. Independence in preferences is also useful. By preferential *independence* Bogetoft (2012) means that the ranking of the values of one dimension is unaffected by the values of the other criteria. It is stated that we always like more of a given output irrespective of the values of the other inputs and outputs, and similar for the inputs we always like less. Dyson et al. (2001) conclude that one should not in general omit correlated variables (within inputs as well as within outputs). An exception from this is if the variables measure approximately the same feature or attribute of the production function, as correlation then reflects dependence. Tests of correlation between inputs and outputs should be positive indicating that increasing an input should increase the output, and vice versa. These are an ideal set of conditions, which presumes availability of sufficient data of high quality. However, even in cases where less than perfect data are available, the data envelopment approach to ranking and analysing offers for their cost effectiveness may still be quite informative and support a transparent and effective ranking and selection of offers (Dyson et al. 2001).

When choosing the set of variables to include in a cost-effectiveness analysis in practice, one should consider the degrees of freedom. The number of inputs and outputs should allow for discrimination between the DMUs. The rule of thumb is that the number of DMUs should be larger than 2 times the number of inputs times the number of outputs (Dyson et al. 2001). If there are too many variables it is not possible to identify efficiency gain. Bogetoft (2012) recommends that the number of DMUs should exceed 3 times the number of inputs plus the number of outputs. The reason for this limit is that the more dimensions the cost-effectiveness measure span, the more DMUs will be present at the frontier as at least the DMU with the highest performance in a dimension will be at the frontier, assuming constant return to scale.

3. Pricing offers using a yard stick procedure

Thorsen et al. (2018) described the potential for applying pricing methods that can resolve procurement auctions with as little *a priori* information collection efforts as possible, yet still handle the fact that cost information is private to suppliers. Specifically, the use of DEA for yard stick pricing in procurement auctions has been studied (Bogetoft and Nielsen 2008), and research efforts have addressed the potential for applying this to public procurements schemes much like the Danish biodiversity set aside scheme (Hougaard et al. 2016; Nielsen et al. 2017).

The ambition of research literature is to determine procedures that can bring if not first-best optimal outcomes then at least very good approximations. It is also the ambition that this can be obtained without costly information collection efforts from both suppliers (in this case the private forest owners) and the buyer (the state/EPA), while still retaining truth-telling as a useful strategy for the suppliers and applying pricing rules that leave suppliers no worse off *ex post* than their stated offers *ex ante*. As described for the DEA and benchmarking above, this approach also implies that suppliers provide their offers described in terms of attributes. A yard stick based algorithm then calculates a set of efficiency corrected yard stick prices, one for each offer, where each offer is measured against a yard stick defined by the most efficient frontier of all closely related offers. The selected suppliers are paid their stated offer and as well as a calculated, efficiency corrected yard stick price. A yard stick regime may increase incentives for truth telling because each agent is not chosen only based on their own cost and attributes, but also based on the performance of the other forest owners who is offering to give up forestry operations (Bogetoft & Otto, 2011). The buyer then ex post selects the combination of offers that the buyer finds are optimal, given the yard stick prices.

The truth telling strategy is, however, contingent on a number of factors, including the understanding of the yardstick procedure and calculation and the trust in the regulator to perform these calculations fairly. Mettepenningen et al. (2009) discuss how transaction costs influence participation rates in compensation schemes in general. Given that the Danish forest owners at present have no experience with reverse auctions, the selection process etc., the transaction costs might be significantly influencing participation rates and therefore it might be advisable to postpone the application of yard stick pricing methods to a later stage, where both regulator and agents are more experienced in using reverse auctions and in this way implement the mechanism in smaller steps.

4. Principles for selecting offers

In the case we consider here, the principal will be looking for one or more offers to accept among those on offer, taking into consideration the budget constraint. This raises the question of how to select these offers among the set of offers. There are different ways to undertake this dependent on the case and the available information. There is a large literature within data envelopment and multi criteria analysis concerned with the quality and potential usefulness of different approaches (Adler et al., 2009), and more are conceivable, e.g. drawing on welfare economics. We describe and illustrate four different approaches, of which one is an ideal welfare economic abstraction useful as a benchmark. The second represents a simplification of preferences based on assessments of preference weights. The final two examples are technically operational ways to rank all offers, including offers that are equally cost effective. We discuss challenges, merits and relevance in the current context of each. We illustrate these four approaches using the mockup data shown in Figure 1.

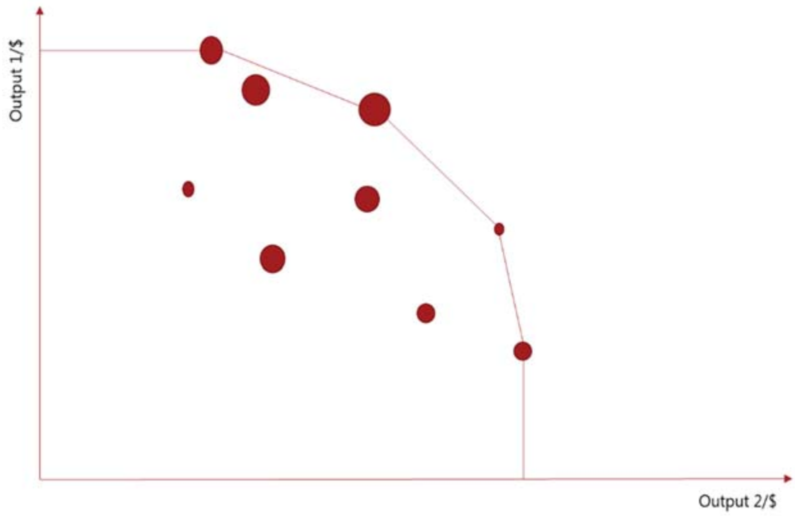

Figure 1 *A set of offers showing different combinations of two output variables. The cost-effective frontier is indicated by the connecting line. The size of each dot represents a secondary quality of each offer not included in the cost effectiveness measure, but of potential*

4.1 Preference based selection

If we assume that output 1 and output 2 tell the principal everything of value about the offers faced in Figure 1, and we are able to describe her/his preferences for these outputs individually and in combination, we may apply these preferences to select the efficient offers, in order of efficiency. In Figure 2, the left panel represents an example of such a selection. The blue curves represent the principal's utility indifference curves across the outputs, which mean that on each of these blue curves all combinations of output 1 and output 2 have the same utility level. However, the further up in the state space (the further northeast) the indifference curve is, the higher the utility and value of the combinations on the curve. Therefore, the principal will select the offer 'A' first, as it touches upon the highest-ranking indifference curve. The next offer selected is 'B', then 'C' and so forth until the principal meets the budget restriction. Note that in this selection procedure, the principal does not stay on the original efficiency frontier, as the principal moves to select 'C'. Updating the frontier as 'A' and 'B' are removed from the set, 'C' gets closer to the frontier, but it is not certain that it will be on the frontier when other offers are selected. It is however the preferred offer. Also note, that in the

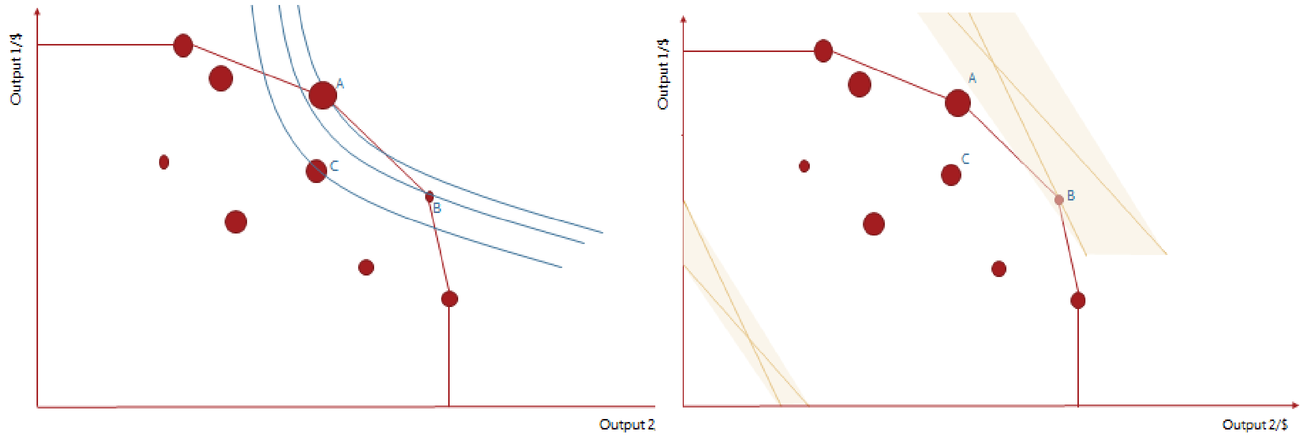

Figure 2 *The left panel shows the selection progression using a set of indifference curves building on well-described preferences over the outputs. The right panel illustrates how one may see the use of approximate weights bands for the* example here, we assumed indifference curves to maintain their form, as offers are selected (consumed). If they change form as offers are selected and hence outputs secured, the procedure is easily adapted to that.

It is not always possible, nor desirable for the principal, to characterize preferences and indifference sets as neat and precise as the indifference curves in the left panel of Figure 2 implies. One approach to approximate these is the use of weight ratio bands, where the relative value of outputs ratios, are believed to be contained within certain boundaries. For example, the principal may believe that the weight of output 1/weight of output 2 is somewhere between 3/2 and 1/1, meaning that output 1 is at least as much worth as output 2, but potentially up to 1.5 as much, but not more. In Figure 2's right hand panel, we have inserted two lines representing such ratios close to the origin of the diagram, and the shaded area represents a band spanned by these ratios. This band may be considered an approximate 'indifference band'. Scaling up along the axes, but maintaining the ratios, implies an increasing band, by definition. Using this band to support selections, we see that for the given weight ratios implied by the bands, the principal would be selecting the small dot called 'B' in the left panel first and so forth as the band moves towards the origin. Again, we note that as offers are picked and outputs hence secured, the principal may assess that the boundaries on the relative weight ratios need to change. However, even the specification of such weight boundaries require some concept of value, and if that is not well defined some degree of subjectivity may be inevitable, which may not be desirable in a context where legitimacy and transparency of a selection procedure is in focus. Furthermore, the approach still assumes that all relevant information for selecting among the offers is captured in output 1 and output 2.

Finally also a note on the budget restriction and the optimality of the entire set selected. Suppose in Figure 2, left panel, that after having selected A and B, the budget available is not large enough to pay for C. Then it may be optimal for the principal to select the next offer, from the best end, that is affordable within the budget restriction. Such discrete problems may arise in any selection algorithm when offers are no freely divisible.

4.2 Super-efficiency based selection

As stressed above, it might not always be possible or desirable for the principal to base the selection of the best set of offers on a measure of preferences or approximate weights. In that case, a selection procedure based on pure technical cost efficiency ranking may be used. One such based approach to ranking is a ranking according to super-efficiency measures. The super-efficiency measure refers to the degree to which a DMU, in our case an offer, could be reduced in outputs and remain on the frontier, or alternatively be increased in input (in our case costs) and remain on the frontier. The super-efficiency measure has the attractive feature that it usually makes it possible to rank all units on the efficient frontier (Xue and Harker 2002; Chen et al. 2013). The measure is illustrated for the point 'A' in Figure 3.

Removing 'A' from the set of offers implies that the new cost effective frontier includes the dashed line between neighboring offers. The distance between 'A' and the dashed line measures the super-efficiency of 'A'. Outputs 1 and 2 can be reduced proportionally or the cost in $ increased until 'A' is on the dashed line.

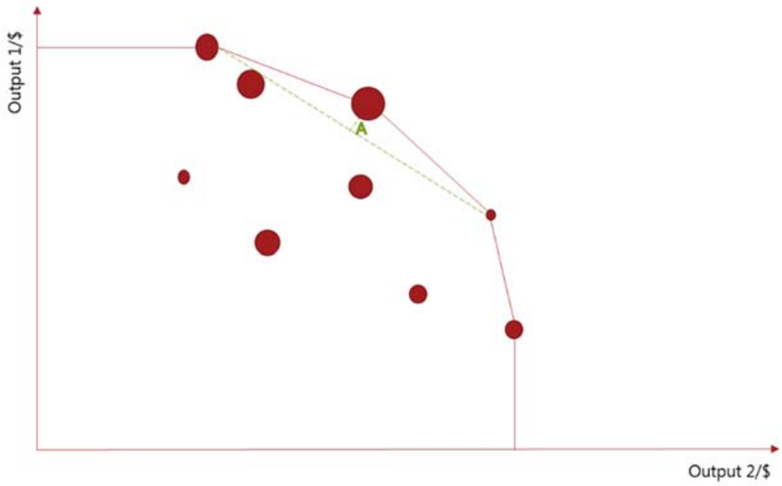

Figure 3 *Illustrating the super-efficiency of the bid 'A'. The distance between 'A' and the dashed line measures the super-efficiency of 'A'. Outputs 1 and 2 can be reduced proportionally or the cost in $ increased until 'A' is on the dashed line.*

Under a constant return to scale technology, it is possible to obtain for each offer on the cost-effective frontier, a measure of super-efficiency may be calculated. Then all offers on the front can be ranked according to this measure, which in general represents a full ranking (as offers will rarely have similar super-efficiency measures). It is a challenge for the super efficiency score that it is undefined for some offers under e.g. varying return to scale technology.

This approach may be of relevance if the principal believes that outputs or inputs (costs) are adjustable *ex post*. By construction, the super-efficiency measure is often highest for offers on the frontier placed in a 'thin' part of the data set, with fewer neighbors and farther between them. This is not an attractive feature, and indeed the super-efficiency measure is suggested as a way to identify outliers in the data. Thus, this measure is likely best suited in data sets that have few outliers and where offers all tend to deliver something on the relevant outputs and no one are outliers, e.g. specializing in only one output axis, in the relevant state space. Finally, also this measure assumes that all relevant information is included in the output variables.

4.3 Secondary criteria based selection

In the above examples, we have worked on the assumption that all information about the offers was included in the input (cost) and the two output variables. This may not be the case, and there may be auxiliary information and secondary indicators describing the offers that are useful for the ranking and selection of the offers on the cost-effective front (Adler et al., 2009). Such secondary indicators could be indicators that are only of value contingent on good performance on the primary output variables included in the efficiency analysis. In the case of the reverse auction of forest biodiversity set aside, that we focus on here, such a secondary indicator could be the total contiguous area of biodiversity interest under the assumption that large, coherent areas have biodiversity potential. This indicator is irrelevant unless the area offered in the offer itself possesses other important attributes that are good indicators of biodiversity protection potential. If that is the case, then the size of the contiguous forest area may be a relevant additional quality criterion useful for ranking and selecting offers. In such a case, it represent part of what underlies unspecified preferences and thus represent a selection strategy likely to bring the technical efficiency based choices closer to the unknown socially optimal choice. We illustrate an application of this in Figure 4.

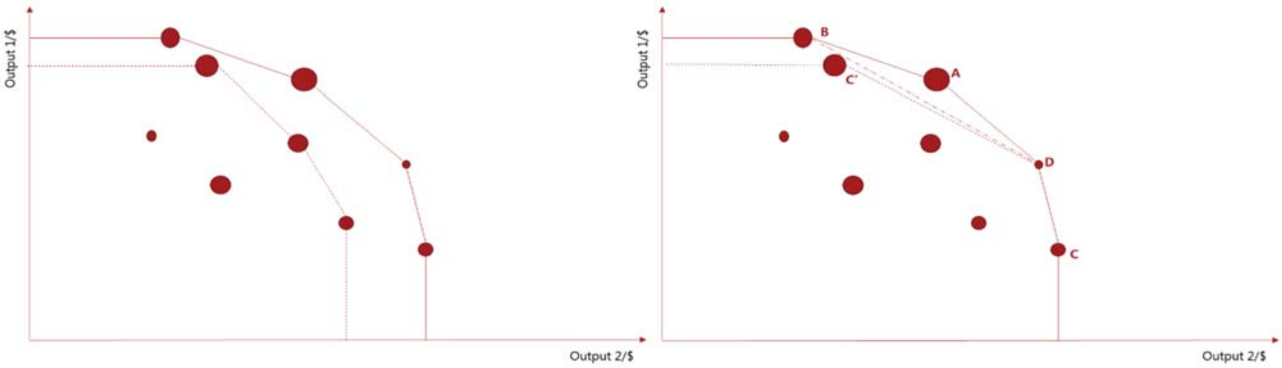

Figure 4 *Demonstrating the use of secondary criteria for selecting bids on the front. The size of each bid marker indicates a secondary criterion. In the left panel, the principal first selects bids on the first calculated front, starting with the largest marker and so on. If this does not exhaust budget, she moves on to the next nested front indicated by the dashed lines, and select from the largest bid marker until budget is exhausted. In the right hand panel, the principal selects the bid with the largest marker on the first front, 'A', recalculate the front without 'A' as indicated by the next dashed line. On the second front, she again selects the biggest bid marker, 'B', recalculates and so on.*

In Figure 4, the size of each offer marker indicates a secondary criterion. In the left panel, the principal first selects offers on the first calculated front, starting with the largest marker and so on. If this does not exhaust her/his budget, she moves on to the next nested front indicated by the dashed lines, and select from the largest offer marker until the budget is exhausted. Note how this procedure implies small markers on the first front is selected over larger markers on the second front. This may be perfectly sensible if the secondary indicator holds little information of value about the offers. The right hand panel in Figure 4 shows an alternative approach. Here the principal selects the offer with the largest marker on the first front, 'A', and then recalculate the front without 'A' as indicated by the next dashed line. On the second front, she/he again selects the biggest offer marker, 'B', recalculates the front and so on. Note how this implies, that she selects 'C'' before 'C' and 'D' on the first front. Which approach is deemed most useful may be an empirical question and depend on what value a secondary criterion may add once a reasonable level of the outputs are secured.

However, it is important to note, that the method ideally should be decided upon *before* the selection is undertaken to avoid any ex-post subjectivities. The choice of method may be based on an expectation of how data will be distributed and in particular whether the principal finds that offers with main emphasis on a single output are of interest or if a more mixed combination of the outputs is preferred is in general preferred in the individual offers. The former corresponds to the left side panel of Figure 4, where offers are selected from the first front identified before any other offers are considered. The latter corresponds to the right hand side panel of Figure 4, where the front is re-calculated after each selection.

5. Evaluating procedures for selecting offers in the reverse auction

In this chapter, we demonstrate how to apply the two technically operational methods (as described in Chapter 4) to rank offers and then select the best offers of forest area for biodiversity conservation purposes. Each offer is characterized by a price and a small set of quantitative variables that are useful indicators of the quality of the area with respect to biodiversity conservation. These variables represent the production technology in the conservation case we study here. In the below analyses, we apply the principles both to a small simulated set of data, and to a larger set of data that draw upon the 2017 and 2018 applications to the Environmental Protection Agency, concerning compensation payments for setting aside forest for biodiversity conservation. Finally, based on our analyses, we conclude this report by describing a short practical procedure for the selection of offers from the reverse auction. The first step in that concerns the selection of variables to include in the analyses.

5.1 Variable selection in practice

There may be variables and characteristics that can be considered as eligibility criteria, e.g. the principal specifies a minimum area size of each offer or will only consider forest ecosystems dominated by native species. The principal will announce such eligibility criteria before the forest owners consider and submit an offer. This requirement also eliminates irrelevant offers and limit quality variables to those fulfilling the *relevance* requirement.

We assume that the principal, when announcing the reverse auction, lists a set of variables that represent information to be provided by the forest owner along with the eligible offer or to be collected or verified through subsequent field observations. As there may be little prior information about the forthcoming offers with respect to what qualities they offer, it is recommendable that the list of variables is sufficiently comprehensive to capture all qualities the principal could find relevant for the efficiency assessment. This procedure combines the *relevance* criteria with the *completeness* criteria at the set level (Dyson et al. 2001; Bogetoft 2012).

Once the offers are submitted, their distribution across all the variables available is investigated. Variables that are only recorded for a small number of offers are usually not suitable for efficiency analysis. The reason is that the efficiency frontier is likely to be poorly described in the dimension represented by the variable, and hence including them could lead to poorly performing choices. This does not imply that important variables should be excluded from the analysis, but if they are uncommon in data they are more suitably used as secondary criteria. The principal should be able to verify variables ex post and collect information of relevant variables if these are suspected to be incorrectly stated in the offer, either as desk top data collection or by field visits. Thus, any incentives to misreport characteristics strategically are ruled out. It is also recommendable to investigate the degree of correlation among output variables. In particular, a strong correlation between variables could reflect that they measure comparable or even overlapping qualities of the offers. As an example see Figure 5 where the Natura 2000 area of the grant application data from 2017 and 2018 is plotted against the total area size of each application. The figure shows, how a number of applications have no recordings of Natura 2000 areas (the number of zeros forming an almost horizontal line) and secondly we see a very high correlation between Nature 2000 area and the total area.

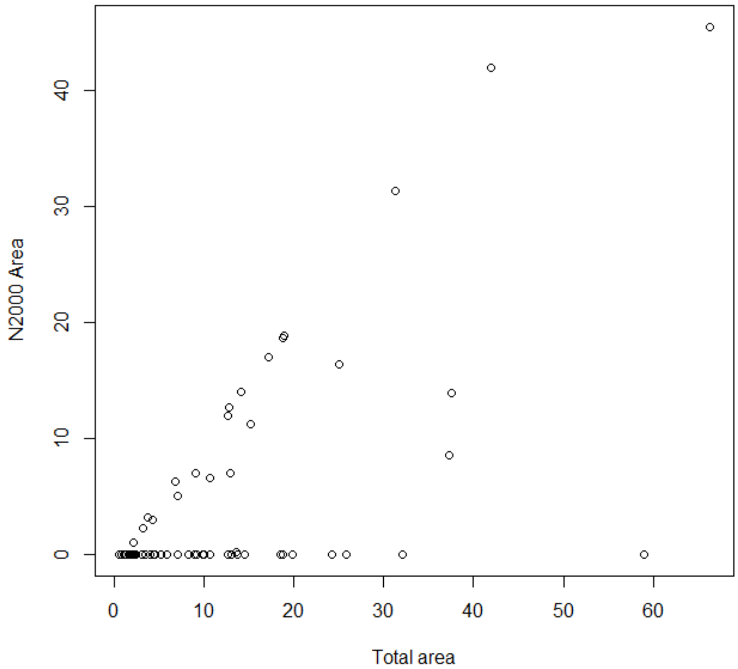

Figure 5 *An example of distribution and correlation of Natura 2000 area against total area using the 2017 and 2018 grant scheme applications.*

It may be possible to transform variables, e.g. by eliminating overlapping elements if possible, or it may be that only one of the closely related variables is selected for the set of variables included in the cost effectiveness analysis. These screening procedures should underpin that the selected set of variables for analyses are all *operational* in a meaningful way and does not include *redundant* information or represent double counting of outcomes (Dyson et al. 2001; Bogetoft 2012).

Among the gross set of information and variables collected may be variables that are mainly of secondary value, e.g. it may be variables that possess information and reflect conservation value, provided other qualities are present in the offer to a sufficient degree. Such variables do not fulfill the *independence* criteria, but the variables may still be of value as secondary selection criteria. Examples of such variables could be proximity to other larger biodiversity conservation areas or the size of contiguous forest conservation offered in the offer.

If the principal undertakes field observations to supplement the data forest owners submitted with their offers, it may be recommendable to undertake an explorative efficiency analysis to select a subset of offers for the field observation exercise. This set needs to be meaningfully larger than the allotted budget can possibly contract. Such an exercise will focus and reduce costs of field observations to the competitive sub-set of offers.

Robustness evaluation with respect to the variables included is advisable if competing variables exist. Similarly, robustness analyses with respect to the selection procedure itself are advisable. For example, it may be worthwhile to investigate if selecting all offers on a frontier before estimating a new frontier and proceeding with selection results in a different set of final offers compared to re-estimation of the frontier for each offer selection. Such robustness checks is best undertaken on data from past rounds of grant allocations so that they inform the selection of procedure, but not affect the selection of the set in a particular reverse auction round.

5.2 A simple example

In the following a procedure for selecting efficient offers under a budget constraint will be exemplified using a comprehensive artificial data set. The same procedure will be used on the data obtained from the previous grant applications with a few modifications.

The first example is a selection between 12 artificial offers of harvesting rights which differ in the output variable N2000 (area of Nature 2000), HNV (area of High Nature Value), and Deadwood (amount of deadwood in the area). The total area is not used as output in this example. The total cost is considered as the input variable. Note that we have one input and three outputs, making us reach the threshold of 12 DMUs (areas) as indicated by Bogetoft (2012) (3 times the number of inputs + number of outputs). Assuming constant return to scale between input and output the efficiency and super-efficiency scores displayed in Table 1 have been calculated using the 'Benchmarking' package for R by Bogetoft & Otto (2015). Table 1 shows that area no 1,5,6 and 12 are efficient.

Table 1 *Data for the 12 areas with efficiency scores*

Area number	Total cost (DKK)	Cost per ha (DKK)	Total area (ha)	N2000 (ha)	HNV in (ha)	Dead-wood (m^3)	Efficiency	Super-efficiency
1	2,000	80	25	1	2	6	1.000	0.990
2	2,040	85	24	2	4	1	0.343	0.343
3	2,070	90	23	3	6	5	0.990	0.986
4	2,090	95	22	4	8	2	0.670	0.670
5	2,100	100	21	5	10	4	1.000	1.041
6	2,100	105	20	6	12	3	1.000	1.194
7	2,090	110	19	7	10	3	0.980	0.980
8	2,070	115	18	8	8	4	0.965	0.965
9	2,040	120	17	9	6	2	0.953	0.953
10	2,000	125	16	10	4	5	0.947	0.947
11	1,950	130	15	11	2	1	0.944	0.944
12	1,890	135	14	12	1	6	1.000	1.270

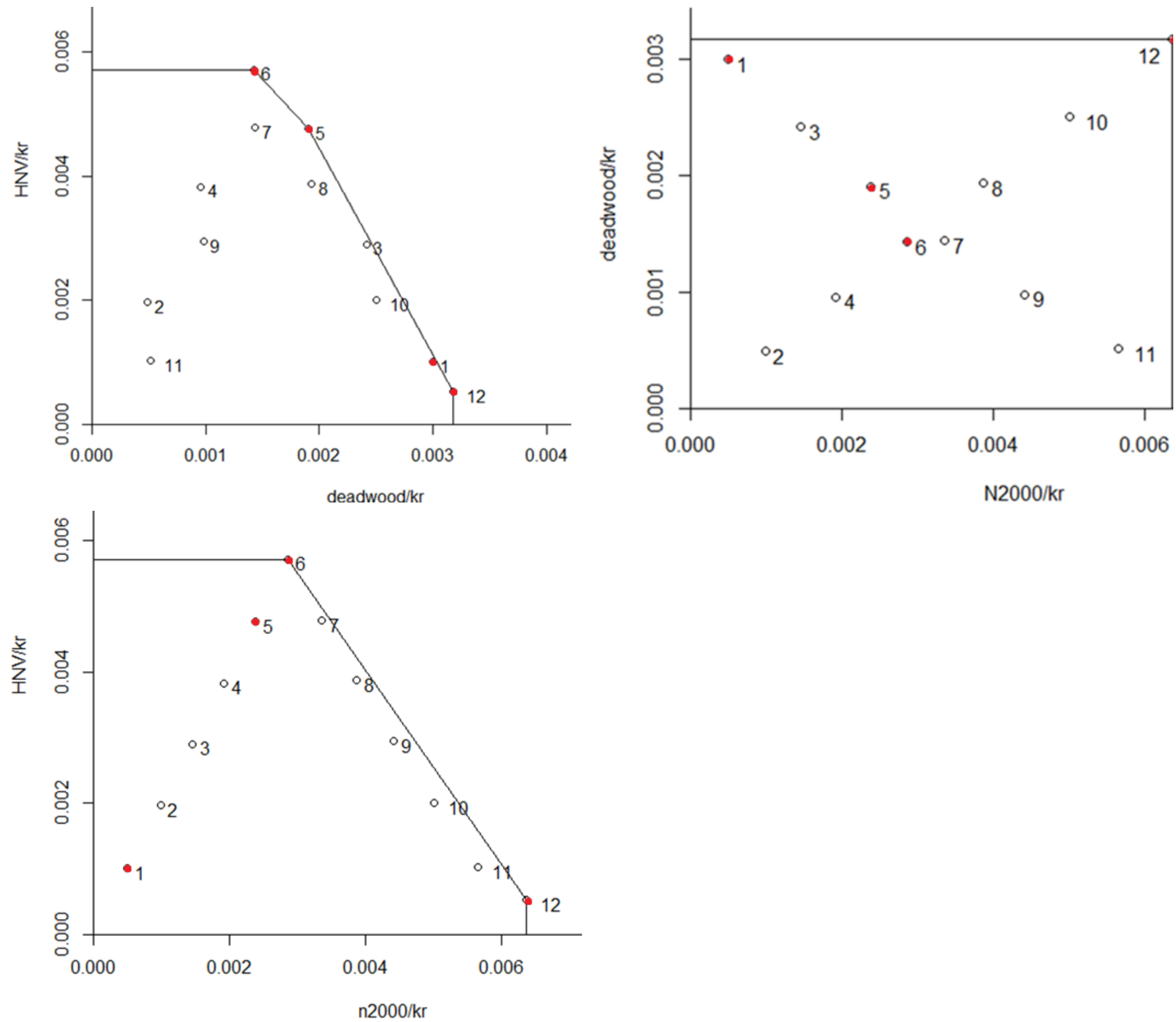

Figure 6 *The different output per DKK plotted against each other, illustrating that offers may be on the frontier in more than one direction, but in these data not in all three directions. Note that the plots are 2D illustrations of a 3D problem, which means none of them contain all relevant information individually.*

In Table 1 we also calculate the super efficiency, which shows the extent to which the cost of an offer could be increased or output qualities be proportionally reduced without becoming inefficient. The super efficiency scores indicate that area no. 12 has the highest super efficiency score, followed by area 6 and 5. If the regulator seeks to contract a number of agents under a budget restriction the super efficiency score can be used for ranking the different agents/offers/areas. In Table 2 below the areas have been sorted according to super efficiency and under an assumed budget restriction of 10 million DKK five areas (almost) are to be selected, i.e. area no 12,6,5,1 and 3 in that order. Note, that the selection of area no 3 will over exhaust the budget – when implementing in practice we assume that some kind of soft budget restriction will take place.

Table 2 *Areas sorted and selected according to super efficiency.*

Area number	Total cost (DKK)	Cost per ha (DKK)	Total area (ha)	N2000 (ha)	HNV (ha)	Dead-wood (m^3)	Efficiency	Super-efficiency	Budget (sum)
12	1,890	135	14	12	1	6	1.000	1.270	1,890
6	2,100	105	20	6	12	3	1.000	1.194	3,990
5	2,100	100	21	5	10	4	1.000	1.041	6,090
1	2,000	80	25	1	2	6	1.000	0.990	8,090
3	2,070	90	23	3	6	5	0.990	0.986	**10,160**
7	2,090	110	19	7	10	3	0.980	0.980	
8	2,070	115	18	8	8	4	0.965	0.965	
9	2,040	120	17	9	6	2	0.953	0.953	
10	2,000	125	16	10	4	5	0.947	0.947	
11	1,950	130	15	11	2	1	0.944	0.944	
4	2,090	95	22	4	8	2	0.670	0.670	
2	2,040	85	24	2	4	1	0.343	0.343	

In the present application of the benchmarking the area size was not included as an output. If the biodiversity indicators chosen for outputs are based on hectares, these will in many cases be highly correlated with the area size (see Figure 4 based on the 78 grant applications from 2017 and 2018 above). Knowing that area size is an important factor for the development of biodiversity in the future, we can incorporate this preference for size in the selection of areas. In Table 3 the areas are now first sorted for efficiency, and then for size. With the same budget constraint the areas can be selected top-down which by coincidence will produce the same set of areas as when we selected after super efficiency, although the selection order is slightly different. When using area size as a parameter, the order for selection is area 1, 5, 6, 12 and 3.

Table 3 *Areas sorted according to efficiency followed by area size.*

Area number	Total cost (DKK)	Cost per ha (DKK)	Total area (ha)	N2000 (ha)	HNV (ha)	Dead-wood (m^3)	Efficiency	Super-efficiency	Budget (sum)
1	2000	80	25	1	2	6	1.000	0.990	2000
5	2,100	100	21	5	10	4	1.000	1.041	4,100
6	2,100	105	20	6	12	3	1.000	1.194	6,200
12	1,890	135	14	12	1	6	1.000	1.270	8,090
3	2,070	90	23	3	6	5	0.990	0.986	**10,160**
7	2,090	110	19	7	10	3	0.980	0.980	
8	2,070	115	18	8	8	4	0.965	0.965	
9	2,040	120	17	9	6	2	0.953	0.953	
10	2,000	125	16	10	4	5	0.947	0.947	
11	1,950	130	15	11	2	1	0.944	0.944	
4	2,090	95	22	4	8	2	0.670	0.670	
2	2,040	85	24	2	4	1	0.343	0.343	

The same calculation of efficiencies and selection process will be demonstrated on the data behind the 78 applications from 2017 and 2018. The first selection process will aim to mimic the selection principles exercised at the 2017 round of applications. Therefore, a fixed price of 110.000 DKK per hectare is assumed, which equals the average price per hectare for the areas assessed in the 2017 round of grant applications. This reflects that for these rounds of applications the price was not a part of the selection process. Furthermore, in the first example only the amount of Nature 2000 areas will be used as output variable. Please note, that the absent variation in total cost due to the fixed price per hectare results in identical efficiencies and super efficiencies. This implies that the efficiency score simply is based on area of N2000/Total area. A selection after the efficiency scores is thus not shown. The areas have been numbered for identification according to size meaning that the biggest area has number 1 and the smallest has number 78. The resulting ordering is shown in Table 4 for the 22 areas with the highest efficiency score, where area size has been used as selection criteria. The full list can be seen in Appendix 3.

***Table 4** Efficiency calculated based on fixed cost as input and N2000 as output. Sorted according to efficiency and area size (only 22 out of 78 areas shown)*

Area number	Total cost (DKK)	Cost per ha (DKK)	Total area (ha)	N2000 (ha)	Efficiency	Selected by EPA in 2017 (2018)	Year
3	4,618	110	42.0	42.0	1.000	1	2017
7	3,446	110	31.3	31.3	1.000	1	2017
12	2,081	110	18.9	18.9	1.000	1	2017
14	2,056	110	18.7	18.7	1.000	1	2017
26	1,399	110	12.7	12.7	1.000	1	2017
16	1,881	110	17.1	17.0	0.994	1	2017
21	1,554	110	14.1	14.0	0.991	0	2017
28	1,392	110	12.7	12.0	0.947	(1)	2018
39	739	110	6.7	6.3	0.938	(1)	2018
49	413	110	3.8	3.2	0.844	0	2018
34	990	110	9.0	7.0	0.775	(1)	2018
17	1,670	110	15.2	11.2	0.740	0	2017
47	464	110	4.2	3.0	0.711	0	2017
37	779	110	7.1	5.0	0.706	0	2018
52	352	110	3.2	2.2	0.696	0	2018
1	7,301	110	66.4	45.5	0.686	(1)	2018
9	2,750	110	25.0	16.4	0.655	(1)	2018
30	1,163	110	10.6	6.6	0.621	(1)	2018
25	1,422	110	12.9	7.0	0.541	0	2017
60	235	110	2.1	1.0	0.467	0	2017
4	4,135	110	37.6	13.9	0.369	(1)	2018
5	4,093	110	37.2	8.5	0.229	0	2017

The first six areas prioritized by the efficiency score and area size correspond to the six areas that were granted compensation in 2017 (indicated by the variable 'Selected by EPA…'). However, there are a number of areas that might be selected for compensation in 2018 which appear rather low in the ordering, i.e. area number 1,4,9 and 30. There are two reasons for that. First, they are 'competing' with areas from the previous year, which might be more competitive, although not selected for compensation in 2017. Second, and more important, due to the simulated fixed price regime used here, all hectares come with the same cost. Because these areas have a relatively large proportion of area that is not Nature 2000 area (which is the only chosen output in this analysis), they are penalized and thus not as efficient as areas with a higher proportion of Natura 2000. The actual costs used for assessing and selecting the offers may differ and explain the deviation between ranking and selection. The same conclusion is valid for a selection according to efficiency, shown in Appendix 3 and 4. This illustrates a consequence of selecting offers based on a hierarchical choice structure, where hectares of Natura 2000 is the (only) dominant criteria and thus overruling cost effectiveness (because in our mock up data cost/ha is constant across bids) and other outputs. Therefore, potentially inefficient choices may result.

The next analysis and selection is based on one input, the simulated total cost and two outputs, the total Nature 2000 area and the amount of area classified as HNV above the score 8. There seems to be a considerable correlation between the amount of Nature 2000 areas and HNV areas, most likely because all Natura 2000 areas are also high HNV value areas, but not the other way around. Thus, to avoid 'double counting' a new HNV variable has been created that only includes the amount of HNV hectares left when the Nature 2000 area has been deducted from the total HNV area. This implies that Natura 2000 area + HNV area <= Total area.

Table 5 *Efficiency calculated based on cost as input and N2000 and HNV as output. Sorted and selected according to efficiency and area size (only 43 out of 78 areas shown).*

Area number	Total cost (DKK)	Total area (ha)	Cost per ha (DKK)	N2000 (ha)	Modified HNV (ha)	Efficiency	Selected by EPA in 2017 (and 2018)	Year
3	42	4618	110	42	0	1.000	1	2017
5	37	4093	110	9	29	1.000	0	2017
7	31	3446	110	31	0	1.000	1	2017
9	25	2750	110	16	9	1.000	(1)	2018
12	19	2081	110	19	0	1.000	1	2017
14	19	2056	110	19	0	1.000	1	2017
15	18	2032	110	0	18	1.000	0	2017
16	17	1881	110	17	0	1.000	1	2017
21	14	1554	110	14	0	1.000	0	2017
24	13	1430	110	0	13	1.000	0	2017
26	13	1399	110	13	0	1.000	1	2017
28	13	1392	110	12	1	1.000	(1)	2018
32	10	1084	110	0	10	1.000	0	2017
37	7	779	110	5	2	1.000	0	2018
43	5	499	110	0	5	1.000	0	2017
52	3	352	110	2	1	1.000	0	2018

56	2	250	110	0	2	1.000	0	2017
65	2	206	110	0	2	1.000	0	2017
67	2	187	110	0	2	1.000	0	2017
68	2	184	110	0	2	1.000	0	2017
71	2	172	110	0	2	1.000	0	2017
73	1	133	110	0	1	1.000	0	2017
76	1	87	110	0	1	1.000	0	2017
77	1	55	110	0	1	1.000	0	2017
53	3	331	110	0	3	0.997	0	2017
63	2	229	110	0	2	0.987	0	2018
8	26	2845	110	0	25	0.984	0	2018
6	32	3528	110	0	32	0.982	0	2018
2	59	6490	110	0	57	0.966	0	2017
42	5	502	110	0	4	0.951	0	2018
47	4	464	110	3	1	0.948	0	2017
39	7	739	110	6	0	0.938	(1)	2018
4	38	4135	110	14	21	0.923	(1)	2018
38	7	770	110	0	6	0.903	0	2018
23	14	1496	110	0	12	0.889	0	2018
55	2	257	110	0	2	0.855	0	2017
49	4	413	110	3	0	0.844	0	2018
72	1	141	110	0	1	0.781	0	2017
34	9	990	110	7	0	0.775	(1)	2018
25	13	1422	110	7	3	0.773	0	2017
1	66	7301	110	46	6	0.770	(1)	2018
17	15	1670	110	11	0	0.740	0	2017
30	11	1163	110	7	0	0.621	(1)	2018

The prioritizing is shown in Table 5 above. Compared to the results in Table 4 we see that for instance area number 5 and 9 now are within top ten of the list due to inclusion of HNV area as an output. However, area number 1 is now even further down the list appearing as number 41 on the list still due to the relatively large proportion of hectares neither being Nature 2000 nor HNV. Again we stress, that the shown simulation uses assumed costs and not observed costs, and the results therefore does not represent an evaluation of the past choices. We note that in Table 5, the selection can be undertaken using the efficient frontier and then using e.g. the area size as a secondary criterion. This ignores any preferences over Natura2000 and HNV-area apart from more being better than less. As costs are constant across alternatives in Table 5, they do not affect the efficiency ranking in the simulation. In a real auction situation, this would of course be different, as cost would vary and perhaps influence efficiency ranking substantially.

6. A step-by-step guide for implementing the efficiency selection of offers

Here we briefly describe a step-by-step guide to implement a reverse auction with a consistent DEA based efficiency focused selection of offers.

1. Announce auction with adapted guidelines, cf. below., and collect database of offers made
2. Investigate distribution and correlation of biodiversity quality variables of offers. If possible and necessary, transform variables if overlapping, e.g. using GIS analysis
3. Select the variables to be included as outputs in the benchmarking analysis, and decide also on possible auxiliary selection criteria
4. Decide on method to analyze and select offers based on an assessment of the relevance of offers that mainly perform on one or few axes relative to offers that provide a mix of outputs. (see last paragraph of Section 4)
5. To prepare for field verification and supplementary data collection: Run the benchmarking algorithm and select on the efficient frontier(s) offers that exhaust the budget, possibly using auxiliary criteria. Select also a number of extra areas on the frontier(s) above the budget constraint, to ensure a sufficiently large set of high performing offers are available for subsequent stages.
6. Undertake field verification of data stated in offers, including observations and measurement of additional variables
7. Determine final set of variables, possibly including field measures, and auxiliary criteria, to be used in final selection of offers
8. Run benchmarking algorithm with the refined set of quality variables and undertake the selection of efficient offers according to the selected approach until the budget is exhausted

7. Necessary changes to the Government Order (Bekendtgørelse)

The current Government Order (GO) related to the grant scheme of setting aside untouched forest for biodiversity purposes (BEK 776, 19/06/2017) and the matching guide need to be changed in a few but crucial ways to facilitate the use of a reversed auction scheme and a consistent basis for selection of the best set of offers. We will here suggest a few changes, which we find essential for efficiency. However, any legal implications must be reviewed with appropriate specialists before implementation. When using a reversed auction all participating forest owners must submit an offer to sell their harvesting rights instead of applying for a grant. Therefore, all occurrences of 'application' and 'apply' should be replaced by 'offer' and' make an offer'.

The selection or prioritizing of offers is regulated in Chapter 2, more specifically in §8. Here it is important to state that all offers will be subject to an efficiency evaluation based on a non-exhaustive set of criteria listed in an unranked manner, and scored relative to all other incoming offers. It should also be stated, that the offers made by forest owners will be ranked according to efficiency and selection for grants will be from the top of this ranking according to a transparent, data informed criteria. The non-exhaustive list of criteria could include different measures likely to correlate with biodiversity potential (size of Natura2000 areas, area with High Nature Value scoring over some threshold or other acknowledged measures), tree species and age class distribution, amount of deadwood/number of old trees, other adjoining areas of high biodiversity value (including other offers) etc.

For practical reasons it should be stated here or in §10 that the Ministry of Environment and Food is not obligated to spend the full margin budget set aside for the current year for the reverse auction and that it is always entitled to refuse offers that judged from experience are inefficient from a cost perspective. In §10 it should also be stated that individual grant sizes are determined by the offer from the forest owner.

As previously mentioned, a successful outcome of a reverse action is contingent on sufficient suppliers competing for the contract(s). The fact that a permanent restriction is a rather extensive intervention that also affects future generations we acknowledge that this might affect the participation rate, i.e. the willingness to state an offer. Therefore, we suggest adding a window of regret for the forest owner. The window of regret could be included in the present §17. This implies that within a certain period, e.g. 15 or 20 years, the forest owner is given the option to ask for a cancellation of the registration of non-touched forest, e.g. within a month. The conditions for withdrawing should also be stated here. We suggest that the forest owner is required to refund the Ministry with the largest of two calculations; a) the original payment including the accrued interest in the period from payment to cancelation using an appropriate interest rate (disconto + mark-up), or b) the present value of the forest stand at the time of cancellation.

See also Appendix 2 for a Danish version of the recommended changes.

8. Conclusion

The present note describes relevant issues when the compensation of forest owners for giving up forestry operations is changed from a grant scheme to a reverse auction. When selecting between forest owners who are willing to give up forestry operations against a payment in order to conserve biodiversity, the policy relevant question becomes how to choose these areas, among several offers, so that the best biodiversity conservation potential is secured for the budget spend.

We suggest an efficient multi-attribute benchmarking procedure to select between the offered areas using data envelopment analysis (DEA), which ensures a focus on efficiency in decisions. Benchmarking is a comparative approach for the regulator, in this case the Danish Environmental Protection Agency, to identify the relative performance of the offers from forest owners, given the specified price for giving up forestry operations and the specific qualities of the area. DEA is a mathematical programming method for estimating production frontiers and evaluating the relative efficiency of different offers. We describe how the specific qualities used for analyzing the offers should be relevant, complete, operational, independent, and non-redundant.

We describe and illustrate four different approaches to select between offers from forest owners, of which one is an ideal welfare economic abstraction useful as a benchmark. The second represents a simplification of preferences based on assessments of preference weights. The final two examples are technically operational ways to rank all bids, including offers that are equally cost effective. We discuss challenges, merits and relevance in the current context of each.

Finally, the current governmental executive order needs modifications in order to accommodate for the selection process of a reversed auction. We therefore provide suggestions regarding how to change the existing executive order to allow for an efficient selection of bids.

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Appendix 1: The R syntax used for selection

```
 rm(list=ls())
## Pakken 'Benchmarking' skal installeres første gang man bruger programmet
library(Benchmarking)

## Oprettelse af 'kunstige' data
data<- data.frame(
  areano=c(1:12),
  cost=c(2000,2040,2070,2090,2100,2100,2090,2070,2040,2000,1950,1890),
  costha=c(80,85,90,95,100,105,110,115,120,125,130,135),
  ha=c(25:14),
  n2000=c(1:12),
  hnv=c(2,4,6,8,10,12,10,8,6,4,2,1),
  deadwood=c(6,1,5,2,4,3,3,4,2,5,1,6))

## Beregning af cost ratios
n2000_cost<-data$n2000/data$cost
ha_cost<-data$ha/data$cost
hnv_cost<-data$hnv/data$cost
deadwood_cost<-data$deadwood/data$cost

## Et input, den totale omkostning per areal
x<-data$cost

## Tre output; deadwood, Natura2000 areal og HNV
y<- with(data, cbind(deadwood, n2000,hnv))

## Efficientsberegning
e_crs<- dea(x,y, RTS="drs",ORIENTATION="in")
e<-eff(e_crs)

esup<-sdea(x,y,RTS="crs", ORIENTATION="in")
super<-eff(esup)

## Her tilføjes de to efficiensberegninger til data
data<- cbind(data,e, super)

## Oprettelse af tabeller med de anvendte data
##Tabel 1, sorteret efter arealnummer
tabel1<-data

##Tabel 2, sorteret efter super efficiens
tabel2 <- data[order(-data$super),]

##Tabel 3, sorteret efter areal
tabel3 <- data[order(-data$e,-data$ha),]
```

```
##Plotter efficiens som vist i første panel i Figur 6 (deadwood_cost/hnv_cost)
x<-deadwood_cost
y<- with(data, cbind(hnv_cost))
dea.plot(x,y,txt=TRUE,RTS="crs", ORIENTATION="out",xlab="Deadwood/kr", ylab="HNV/kr")

##Plotter efficiens som vist i sidste (nederste) panel i Figur 6 (N2000_cost/HNV_cost)
x<-n2000_cost
dea.plot(x,y,txt=TRUE,RTS="crs", ORIENTATION="out",xlab="N2000/kr", ylab="HNV/kr")

##Plotter efficiens som vist i anden panel (th) i Figur 6 (N2000_cost/Deadwood_cost)
y<- with(data, cbind(deadwood_cost))
dea.plot(x,y,txt=TRUE,RTS="crs", ORIENTATION="out",xlab="N2000/kr", ylab="Deadwood/kr")
```

Appendix 2: Danish translation of Necessary changes to the Government Order (Bekendtgørelse)

I den nuværende Bekendtgørelse ændres sprogbruget fra at omtale tilskud til at omtale det afgivne tilbud.

Specifikt er det i Bekendtgørelsens § 8, at der skal ske en særlig omhyggelig tilretning. Det bør fx fremgå, at afgivne tilbud om at henlægge til privat urørt skov, der opfylder betingelserne i § 4, bliver underkastet en omkostningseffektivitetsvurdering, hvor det enkelte tilbud scores i forhold til alle andre på et sæt kriterier. Det bør kort beskrives, at tilbud derefter udvælges primært efter størst omkostningseffektivitet, dog således at bud, der scorer ens på omkostningseffektivitet, rangordnes med sekundære supplerende kriterier. I §8 skal der også oplistes et sæt kriterier, der kan indgå i effektivitetsvurderingen og udvælgelsen. Det er vigtigt, at listen ikke angiver en prioriteringsfølge, men fx ser sådan her ud:

- Tilstedeværelse og arealstørrelse af kortlagte Natura 2000 skovnaturtyper tilstandsklasse 1 og 2 indenfor tilsagnsarealet.
- Tilstedeværelse og arealstørrelse af kortlagte Natura 2000 skovnaturtyper tilstandsklasse 3 til 5 indenfor tilsagnsarealet.
- Tilstedeværelse og arealstørrelse af HNV-skov med en score på 8 eller derover indenfor tilsagnsarealet, eller arealet af værdifuld skovnatur dokumenteret gennem af forelæggelse af en driftsplan indeholdende en biotopregistrering med værdifuld skovnatur indenfor tilsagnsarealet. Biotopregistrering skal være dækkende for hele tilsagnsarealet.
- Aldersklassefordelingen/ andel af areal med gamle træer (over xx år)
- Mængden af dødt ved opgjort efter taksering
- Areal af sammenhængende arealer, også på tværs af tilbud.
- Andre ansøgninger.

Det skal sikres, at tilfældigheder og misbrug ikke truer en fornuftig anvendelse af statens midler og ordningens grundlæggende kvalitet. Derfor bør det på passende sted fremgå, at såfremt et tilbud efter prioritering ikke kan rummes inden for beløbsrammen, men hvor beløbsrammen ikke er brugt, kan Miljøstyrelsen fastsætte nærmere vilkår og frister for evt. tilpasning af et tilbud. Det bør ligeledes fremgå, at Miljøstyrelsen ikke er forpligtet på at bruge beløbsrammen et givet år, samt at Miljøstyrelsen kan afvise tilbud, der erfaringsbaseret vurderes som værende ineffektivt dyre.

Sprogbruget omkring finansiering bør ændres så det fremgår at accepterede tilbud tilkøbes med udgangspunkt i et beløb, der fastsættes på finansloven, og at betalingen for det enkelte tilbud fastsættes i overensstemmelse med tilbud fra den enkelte skovejer. Det beløb, der fastsættes for det enkelte år, kan opdeles i flere ansøgningsrunder, som fastsættes nærmere af Miljøstyrelsen, men da det er vigtigt hver budrunde er passende stor for at sikre konkurrence opfordres der til forsigtighed at udbyde flere runder årligt.

Det er vigtigt, at der samles store mængder bud i en given budrunde. Derfor skal det også i den nye ordning fremgå, at tilbud om henlæggelse af urørt skov skal være modtaget af Miljøstyrelsen inden en frist, som fastsættes af styrelsen., og at dette indebærer, at et tilpasset tilbudsskema, jf. ovenfor, som fremgår af

Miljøstyrelsens hjemmeside, skal udfyldes og indsendes til styrelsen. Det skal forsat være sådan at særligt mangelfulde tilbud kan returneres til ansøgeren uden nærmere behandling.

Det er også forsat nødvendigt at understrege at tilsagn kan bortfalde, hvis kriterierne for støtteberettigelse ikke opfyldes, og at eventuelt udbetalte midler i så fald skal tilbagebetales.

Derudover foreslår vi, at der etableres et fortrydelsesvindue, der opstår efter en længere årrække og er åben i en kort periode, fx en måned. I det vindue kan ejer anmode om aflysning af tinglysningen foretaget efter denne bekendtgørelse. Ved en sådan aflysning tilbagebetales det største beløb af enten a) det udbetalte tilskud med tillæg af renter efter renteloven eller b) kapitalværdien af den stående bevoksning på aflysningstidspunktet [værdien af den stående masse plus evt. tillæg]. Formålet er at reducere den oplevede risiko for skovejerne, der kan være i forhold til fremtidige ejerforhold med mere, og dermed reducere de omkostninger skovejerne vil kræve dækkede gennem deres tilbud. Sådan et vindue kan dermed øge omkostningseffektiviteten.

Appendix 3: All 78 areas sorted according to area size, output N2000

Area number	Total cost (DKK)	Cost per ha (DKK)	Total area (ha)	N2000 (ha)	Efficiency	Selected	Year
3	4,618	110	42.0	42.0	1.000	1	2017
7	3,446	110	31.3	31.3	1.000	1	2017
12	2,081	110	18.9	18.9	1.000	1	2017
14	2,056	110	18.7	18.7	1.000	1	2017
26	1,399	110	12.7	12.7	1.000	1	2017
16	1,881	110	17.1	17.0	0.994	1	2017
21	1,554	110	14.1	14.0	0.991	0	2017
28	1,392	110	12.7	12.0	0.947	1	2018
39	739	110	6.7	6.3	0.938	1	2018
49	413	110	3.8	3.2	0.844	0	2018
34	990	110	9.0	7.0	0.775	1	2018
17	1,670	110	15.2	11.2	0.740	0	2017
47	464	110	4.2	3.0	0.711	0	2017
37	779	110	7.1	5.0	0.706	0	2018
52	352	110	3.2	2.2	0.696	0	2018
1	7,301	110	66.4	45.5	0.686	1	2018
9	2,750	110	25.0	16.4	0.655	1	2018
30	1,163	110	10.6	6.6	0.621	1	2018
25	1,422	110	12.9	7.0	0.541	0	2017
60	235	110	2.1	1.0	0.467	0	2017
4	4,135	110	37.6	13.9	0.369	1	2018
5	4,093	110	37.2	8.5	0.229	0	2017
23	1,496	110	13.6	0.2	0.018	0	2018
2	6,490	110	59.0	0.0	0.000	0	2017
6	3,528	110	32.1	0.0	0.000	0	2018
8	2,845	110	25.9	0.0	0.000	0	2018
10	2,665	110	24.2	0.0	0.000	0	2017
11	2,187	110	19.9	0.0	0.000	0	2018
13	2,059	110	18.7	0.0	0.000	0	2017
15	2,032	110	18.5	0.0	0.000	0	2017
18	1,593	110	14.5	0.0	0.000	0	2017
19	1,593	110	14.5	0.0	0.000	0	2017
20	1,593	110	14.5	0.0	0.000	0	2018
22	1,511	110	13.7	0.0	0.000	0	2018
24	1,430	110	13.0	0.0	0.000	0	2017
27	1,392	110	12.7	0.0	0.000	0	2017
29	1,164	110	10.6	0.0	0.000	0	2017
31	1,097	110	10.0	0.0	0.000	0	2018
32	1,084	110	9.9	0.0	0.000	0	2017
33	1,001	110	9.1	0.0	0.000	0	2017

35	979	110	8.9	0.0	0.000	0	2017
36	901	110	8.2	0.0	0.000	0	2018
38	770	110	7.0	0.0	0.000	0	2018
40	635	110	5.8	0.0	0.000	0	2018
41	561	110	5.1	0.0	0.000	0	2017
42	502	110	4.6	0.0	0.000	0	2018
43	499	110	4.5	0.0	0.000	0	2017
44	498	110	4.5	0.0	0.000	0	2018
45	485	110	4.4	0.0	0.000	0	2017
46	484	110	4.4	0.0	0.000	0	2018
48	440	110	4.0	0.0	0.000	0	2017
50	377	110	3.4	0.0	0.000	0	2018
51	371	110	3.4	0.0	0.000	0	2018
53	331	110	3.0	0.0	0.000	0	2017
54	329	110	3.0	0.0	0.000	0	2017
55	257	110	2.3	0.0	0.000	0	2017
56	250	110	2.3	0.0	0.000	0	2017
57	242	110	2.2	0.0	0.000	0	2018
58	242	110	2.2	0.0	0.000	0	2018
59	240	110	2.2	0.0	0.000	0	2018
61	233	110	2.1	0.0	0.000	0	2017
62	232	110	2.1	0.0	0.000	0	2017
63	229	110	2.1	0.0	0.000	0	2018
64	218	110	2.0	0.0	0.000	0	2017
65	206	110	1.9	0.0	0.000	0	2017
66	206	110	1.9	0.0	0.000	0	2018
67	187	110	1.7	0.0	0.000	0	2017
68	184	110	1.7	0.0	0.000	0	2017
69	184	110	1.7	0.0	0.000	0	2018
70	180	110	1.6	0.0	0.000	0	2018
71	172	110	1.6	0.0	0.000	0	2017
72	141	110	1.3	0.0	0.000	0	2017
73	133	110	1.2	0.0	0.000	0	2017
74	116	110	1.1	0.0	0.000	0	2017
75	111	110	1.0	0.0	0.000	0	2018
76	87	110	0.8	0.0	0.000	0	2017
77	55	110	0.5	0.0	0.000	0	2017
78	55	110	0.5	0.0	0.000	0	2017

Appendix 4: All 78 areas, output N2000 and HNV, sorted according to area size

Area number	Total cost (DKK)	Cost per ha (DKK)	Total area (ha)	N2000 (ha)	Modified HNV (ha)	Efficiency	Selected	Year
3	42	4618	110	42	0	1.000	1	2017
5	37	4093	110	9	29	1.000	0	2017
7	31	3446	110	31	0	1.000	1	2017
9	25	2750	110	16	9	1.000	1	2018
12	19	2081	110	19	0	1.000	1	2017
14	19	2056	110	19	0	1.000	1	2017
15	18	2032	110	0	18	1.000	0	2017
16	17	1881	110	17	0	1.000	1	2017
21	14	1554	110	14	0	1.000	0	2017
24	13	1430	110	0	13	1.000	0	2017
26	13	1399	110	13	0	1.000	1	2017
28	13	1392	110	12	1	1.000	1	2018
32	10	1084	110	0	10	1.000	0	2017
37	7	779	110	5	2	1.000	0	2018
43	5	499	110	0	5	1.000	0	2017
52	3	352	110	2	1	1.000	0	2018
56	2	250	110	0	2	1.000	0	2017
65	2	206	110	0	2	1.000	0	2017
67	2	187	110	0	2	1.000	0	2017
68	2	184	110	0	2	1.000	0	2017
71	2	172	110	0	2	1.000	0	2017
73	1	133	110	0	1	1.000	0	2017
76	1	87	110	0	1	1.000	0	2017
77	1	55	110	0	1	1.000	0	2017
53	3	331	110	0	3	0.997	0	2017
63	2	229	110	0	2	0.987	0	2018
8	26	2845	110	0	25	0.984	0	2018
6	32	3528	110	0	32	0.982	0	2018
2	59	6490	110	0	57	0.966	0	2017
42	5	502	110	0	4	0.951	0	2018
47	4	464	110	3	1	0.948	0	2017
39	7	739	110	6	0	0.938	1	2018
4	38	4135	110	14	21	0.923	1	2018
38	7	770	110	0	6	0.903	0	2018
23	14	1496	110	0	12	0.889	0	2018
55	2	257	110	0	2	0.855	0	2017
49	4	413	110	3	0	0.844	0	2018
72	1	141	110	0	1	0.781	0	2017

34	9	990	110	7	0	0.775	1	2018
25	13	1422	110	7	3	0.773	0	2017
1	66	7301	110	46	6	0.770	1	2018
17	15	1670	110	11	0	0.740	0	2017
30	11	1163	110	7	0	0.621	1	2018
44	5	498	110	0	2	0.544	0	2018
60	2	235	110	1	0	0.467	0	2017
70	2	180	110	0	1	0.447	0	2018
35	9	979	110	0	2	0.225	0	2017
31	10	1097	110	0	1	0.117	0	2018
33	9	1001	110	0	1	0.110	0	2017
10	24	2665	110	0	0	0.000	0	2017
11	20	2187	110	0	0	0.000	0	2018
13	19	2059	110	0	0	0.000	0	2017
18	14	1593	110	0	0	0.000	0	2017
19	14	1593	110	0	0	0.000	0	2017
20	14	1593	110	0	0	0.000	0	2018
22	14	1511	110	0	0	0.000	0	2018
27	13	1392	110	0	0	0.000	0	2017
29	11	1164	110	0	0	0.000	0	2017
36	8	901	110	0	0	0.000	0	2018
40	6	635	110	0	0	0.000	0	2018
41	5	561	110	0	0	0.000	0	2017
45	4	485	110	0	0	0.000	0	2017
46	4	484	110	0	0	0.000	0	2018
48	4	440	110	0	0	0.000	0	2017
50	3	377	110	0	0	0.000	0	2018
51	3	371	110	0	0	0.000	0	2018
54	3	329	110	0	0	0.000	0	2017
57	2	242	110	0	0	0.000	0	2018
58	2	242	110	0	0	0.000	0	2018
59	2	240	110	0	0	0.000	0	2018
61	2	233	110	0	0	0.000	0	2017
62	2	232	110	0	0	0.000	0	2017
64	2	218	110	0	0	0.000	0	2017
66	2	206	110	0	0	0.000	0	2018
69	2	184	110	0	0	0.000	0	2018
74	1	116	110	0	0	0.000	0	2017
75	1	111	110	0	0	0.000	0	2018
78	1	55	110	0	0	0.000	0	2017